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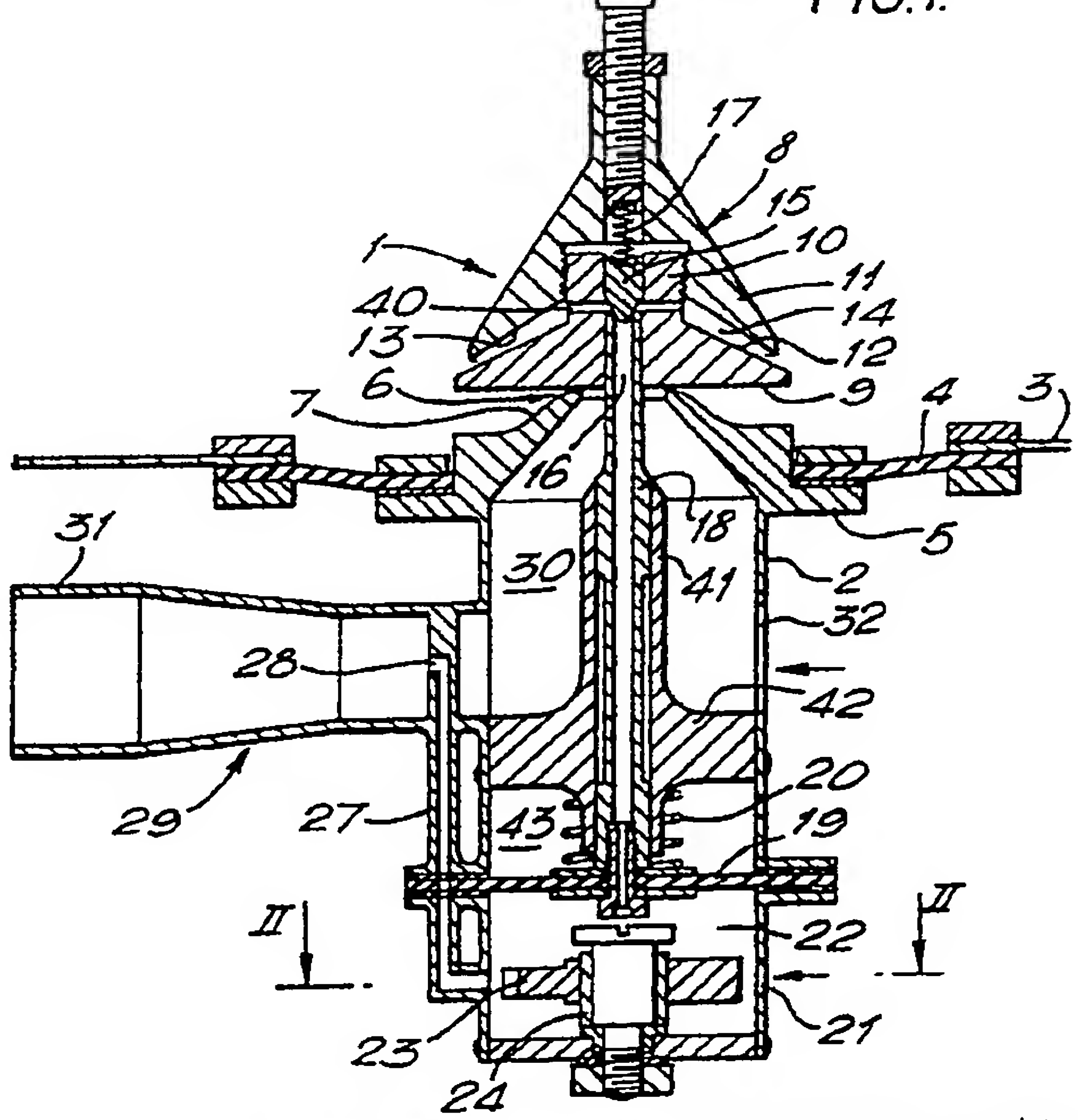
(54) Particulate material entrainment apparatus

(57) Apparatus 1 for connection to a body of particulate material is operable to entrain such material in a flow of transport gas. The apparatus comprises an inlet 6 for particulate material adapted to be disposed in the body thereof, a shield 9 arranged above the inlet, and a transport gas outlet 14 arranged to discharge gas into the body of particulate material above the shield such that the gas flows past the shield and towards the inlet so as to assist flow of the material into the inlet. The shield 9 acts as a closure member biased by a spring 20 to a closed position and upwardly movable to an open position when the apparatus is supplied with transport gas. An eccentric flywheel 23 is arranged to be driven by the transport gas to vibrate the apparatus. Low pressure in venturi 29 caused by flow of gas from bypass pipe 27 works to draw solid in through inlet 6.

FIG.1.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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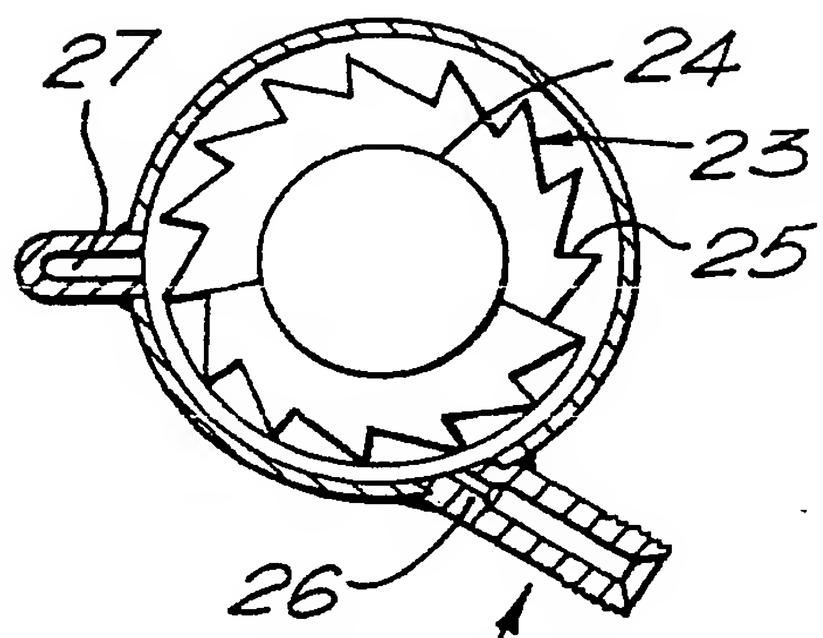
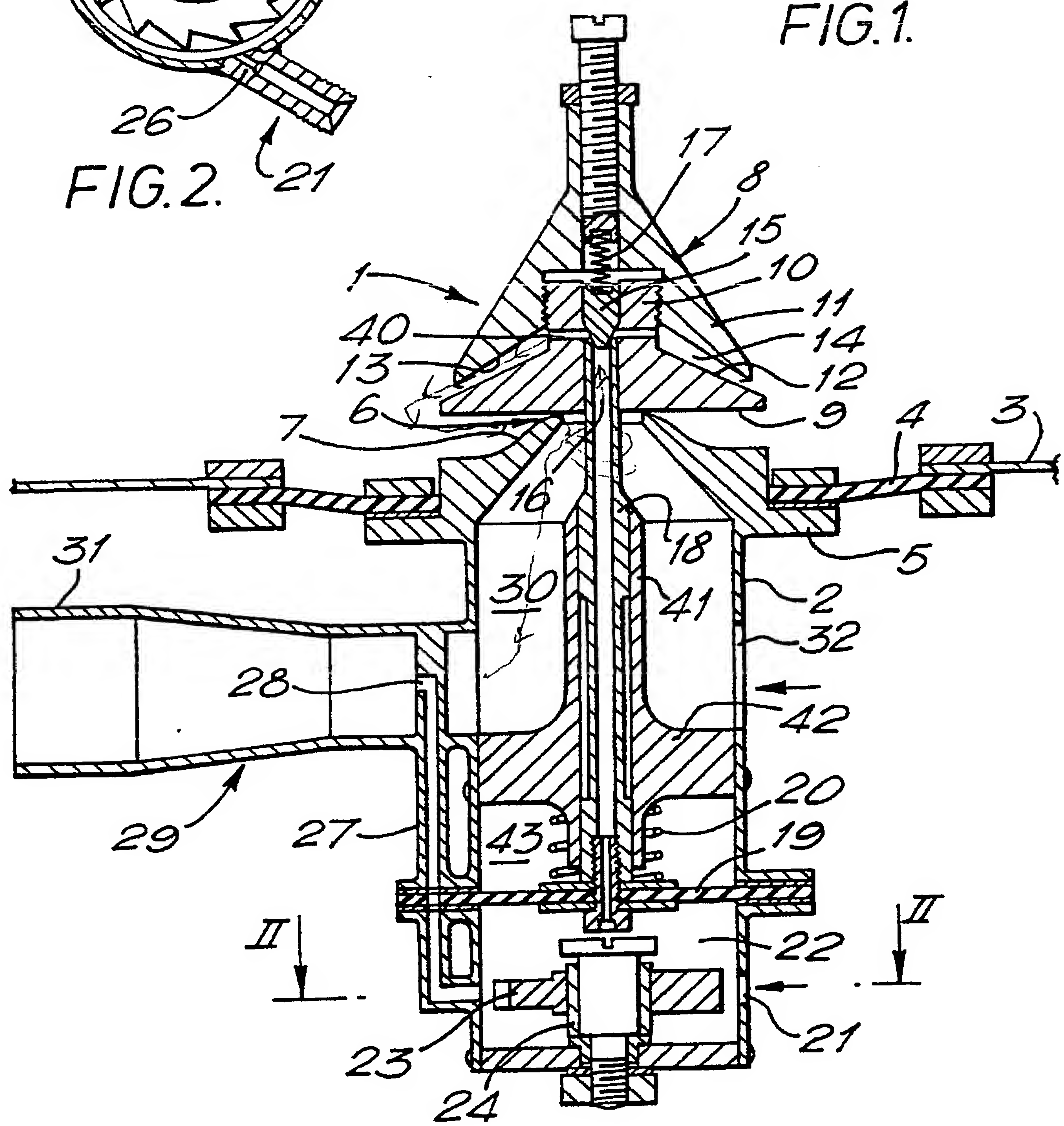


FIG. 2.

FIG. 1.



D scription

Particulate Material Entrainment Apparatus
The invention relates to apparatus for connection to a body of particulate material and operable to entrain such material in a flow of transport gas.

It is knon to feed small doses of powdered chemicals into solid fuel industrial boilers to prevent or reduce the build up of waste materials.

This has been done by inserting a venturi device from above into a drum containing the powder and then feeding compressed air to the device. The powder is entrained in a flow of air which is fed via a pipe into the boiler. In a coal burning boiler, typically 200 grams of powder per tonne of coal may be required to be introduced, and this may involve a fifteen minute discharge of powder at intervals of six to eight hours.

This system is relatively crude and often results in spillage and waste of powder. Furthermore the venturi device buried in the powder may become blocked and to alleviate this difficulty it has been the practice to vibrate the whole drum of powder. The equipment for vibrating the hopper needs to be quite substantial in size and an electric supply is required to power the equipment.

It is known from GB-A-2089330 to provide a system for entraining pulverised coal particles in a flow of nitrogen in which an inlet for the particles is buried therein and is covered by a conical deflector member such that particles pass through the inlet generally horizontally. Nitrogen is fed through a sintered plate disposed below and adjacent the inlet partially to fluidise the pulverised coal.

Viewed from one aspect the invention provides apparatus for connection to a body of particulate material and operable to entrain such material in a flow of transport gas, comprising an inlet for particulate material adapted to be disposed in the body thereof, a shield arranged above the inlet, and a transport gas outlet arranged to discharge gas into the body of particulate material above the shield such that the gas flows past the shield and towards the inlet so as to assist flow of the material into the inlet.

With such apparatus, even if the apparatus has not been operated for an extended period so that the particulate material has compacted or agglomerated to a certain extent, the arrangement of the transport gas outlet ensures that the material is loosened and can enter the apparatus via the inlet to be entrained in the flow of transport gas. The entrained particulate material may then be supplied via the apparatus to the desired location.

The apparatus may for example be installed at the base of a hopper containing particulate material such as a powdered chemical which is to be fed to the combustion chamber of an industrial boiler, since in such circumstances the apparatus is normally required to remain idle for a number of hours and then to be operated for a few minutes. The transport gas may for example be dry; compressed air.

The transport gas outlet may be generally annular in torm, so as to provide a relatively large flow area for the gas discharged into the particulate material whilst keeping down the overall dimensions of the apparatus. The gas outlet may consist of one or more individual flow passages for directing gas into the particulate material body above the shield, but preferably comprises an upwardly facing conical surface located beneath a downwardly facing conical surface to define a conical gas flow passage therebetween, and gas supply means disposed centrally of the conical gas flow passage, whereby in operation the gas flows in a generally radially outward and downward direction. By arranging the gas outlet in this way, when the apparatus is not in use particulate material will nct tend to enter the gas outlet since it would have to rise up the slope of the conical gas flow passage.Furthermore, the relatively large peripheral or cirumferential dimension of the downstream end of the conical gas flow passage reduces any likelihood of blockage. In a preferred form the profiles of the upwardly and downwardly facing conical surfaces are such that the conical gas flow passage narrows in the downstream direction, since a narrow passsage opening at the downstream end of the flow passage also inhibits back flow of particulate material.

The downwardly facing conical surface may be provided by a member of any convenient shape, but preferably a deflector is provided above the gas outlet which has an upper surface arranged to guide particulate material towards the outlet.

Thus, in the case of a conical gas flow passage, the deflector may have a generally conical upper surface which has a lower edge adjacent to the downstream end of the gas flow passage. With this arrangement particles which are guided down the surface of the deflector may be drawn into the flow of gas discharged from the gas flow passage.

The transport gas may be supplied to the gas outlet in various ways, for example, by means of a tube which passes through the particulate material body, but preferably the gas feed to the outlet passes upwardly through the shield. If the gas outlet is generally annular as discussed above, the gas feed may be connected to the gas outlet by a plurality of radial passages.

Control means may advantageously be provided selectively te terrupt the flow of gas from the gas feed to the gas outlet, for example to limit the maw ..m gas pressure developed in the region of the gas outlet so as to avoid an excessive quantity of particulate material from being drawn into the inlet of the apparatus. The control means may comprise a valve disposed between the gas feed and the gas outlet, the valve being biased to a closed position and movable to an open position by gas pressure in the gas feed, and means communicating the valve with the gas outlet such that pressure developed in the region of the gas outlet acts to move the valve towards the closed position, so that when the gas outlet pressure exceeds a predetermined value the valve is moved to the closed position.Thus, for example, the bias on the valve may be set such that the valve opens at a gas feed pressure of 60psi (4.1 bar) and during operation gas may be supplied at a higher pressure of 80psi (5.5 bar), so that if the pressure developed in the region of tne gas outlet exceeds 20psi (1.4 bar) the valve will close. Such a back pressure of 20psi (1.4 bar! may be developed for example by the weight of the particulate material above the apparatus at the base of a full hopper, and closure of the valve in such circumstances tends to prevent excess particulate material from flowing through the inlet into the apparatus. As the hopper empties, lack of back pressure means that the valve remains open and gas is discharged from the oulet into the particulate material in the normal way.

The bias on the valve may be adjustable so as to vary as desired the value of gas outlet pressure at which the valve is moved to the closed position.

The bias may thus be provided by a compression spring located between a movable valve member and an adjustable screw, whereby rotation of the screw varies the compression of the spring and thus its force on the valve member.

The particulate material inlet is preferably circular or annular and may consist for example of one or more laterally or upwardly facing openings, such opening or openings being protected from excessive ingress of pariculate material by the shield arranged thereabove. The apparatus is preferably arranged to provide a path leading to the particulate material inlet the transverse area of which narrows towards the inlet. since particulate material will normally be drawn into the inlet by providing a low pressure zone downstean thereof, such a narrowing path leading to the inlet achieves a localised lower pressure tending to promote separation of particulate material particles. In a preferred form of the apparatus having an annular or circular inlet, the path is defined between the under surface of the shield and a generally convex surface surrounding the inlet.

The apparatus may include downstream of the particulate material a cavity through which the flow of gas with entrained particles passes in use and which has an opening communicating with atmosphere such that outside air is drawn into the cavity. This arrangement increases the flow rate through the apparatus and serves to reduce the concentration of entrained particles. Thus the particles may undergo a first "dilution" with transport gas when such gas is discharged into the body of particulate material and drawn through the particle inlet, and a second dilution with air drawn into the cavity.

In order to draw the particles and gas/air mixture from the cavity, the apparatus may include downstream of the cavity a nozzle arranged to discharge transport gas into a venturi. Such an arrangement advantageously produces a third dilution of the particles. A further venturi suction system may if desired b provided at a location downstream of the apsaratils to assist transport of the particles to their eventual destination.

It is possible for the particulate material inlet to remain open at all times, with particle entrainment being effected when desired by discharging gas from the gas outlet and providing a low pressure zone downsteam of the inlet. It is however advantageous to provide the inlet with closure means which may be closed when the apparatus is not in operation, and it is particularly preferred for the closure means to be normally biased to a closed position and arranged to be opened when the supply of gas for entraining particulate material is switched on. With such an arrangement when the gas supply is switched off the closure means closes and thus prevents further entry of particles into the apparatus.

If a venturi or other suction system is provided downs team of the apparatus this may be used to remove particle from the apparatus once closure has been effected, so that the apparatus is purged of particles and can remain empty when idle.

Thus viewed from another aspect the invention provides apparatus for connection to a body of particulate material and operable to entrain such material in a flow of transport gas, comprising an inlet for particulate material adapted to be disposed in the body thereof, a transport gas flow system arranged to be supplied with gas to produce low pressure downstream of the particulate material inlet such that in use material is drawn through the inlet and entrained in the gas flow, and closure means for the inlet normally biased to a closed position and automatically movable to an open position in response to gas pressure supplied to the transport gas flow system.

With such an arrangement the closure means will close automatically under the biasing force when the transoort gas supply is switched off.

The transport gas flow system might for example include a chamber at least partly defined by a flexible diaphragm to which the closure means is connected, whereby a change in pressure in the chamber when the gas supply is switched on causes flexing of the diaphragm and consequent opening of the closure means. The closure means may take various forms, but in a preferred arrangement a closure member is arranged vertically above the particulate material inlet and is vertically movable to the open position. This means that particles located above the closure member are disturbed and loosened when the member moves vertically upwardly to open the inlet.

The shield above the inlet referred to earlier may act as the closure member. In a preferred embodiment a hollow push rod connects the flexible diaphragm to the shield to effect opening and closing movement thereof, and the push rod provides a gas passage which communicates the chamber adjacent the diaphragm with the gas outlet arranged above the shield, the passage in the push rod acting as the feed to the gas outlet. The chamber may also be connected to the venturi system referred to above for producing suction downstream of the particulate material inlet. Thus gas supplied to the chamber may perform a number of functions: it may cause flexing of the diaphragm to open the inlet, it may supply gas to the outlet which discharges into the particulate material and it may produce suction downstream of the inlet so that the material is entrained in a flow of gas.

It is desirable to provide the apparatus with vibration means for loosening the particulate material and thereby assisting entrainment thereof.

The vibration means may for example be electrically powered, but it is particularly preferred for it to be drivable by the transport gas supplied to the apparatus. Thus the apparatus can be operated by making a single connection to a supply of transport gas, such as e.g. compressed air which is readily available in most sites where the apparatus is likely to be used, such as boiler houses. The vibration means preferably takes the form of an eccentric flywheel which is rotated by the supply of transport gas to the apparatus. The flywheel will tend to rotate slowly at first, producing low frequency high amplitude vibration for loosening the particulate material, and then as the flywheel accelerates high frequency low amplitude vibration is produced and this assists fluidising of the material.The flywheel may for example be located in the chamber referred to above, so that transport gas supplied to the chamber will perform the additional function of rotating the flywheel.

The apparatus preferably includes means for mounting itself flexibly to a container for the particulate material so that substantially the whole apparatus is vibrated by operation of the vibration means, The flexible mounting means may take the form of a flexible ring connected at its inner periphery to the body of the apparatus and adapted to be connected at its outer periphery to an opening in a particulate material container.

In use, the ring will most advantageously be exposed to the particulate material so that vibration of the ring is transmitted to the material thereby assisting entrainment thereof in the flow of transport gas.

Thus viewed from a further aspect the invention provides apparatus for connection to a container of particulate material and operable to entrain such material in a flow of transport gas, comprising an inlet for particulate material, means for vibrating the apparatus, and means for flexibly mounting the apparatus to the container with the inlet for particulate material disposed in the container, the flexible mounting means being arranged to be exposed to the inside of the container such that in use particulate material is in contact with the mounting means and is vibrated thereby.

The invention also provides a container incorporating apparatus in accordance with any of the aspects of the invention discussed above.

A preferred embodiment of the invention will now be described by way of example and with reference to the accompanying drawings, in which:
Fig. 1 is a vertical section through apparatus in accordance with the invention;
Fig. 2 is a section on the lines II - II of Fig. 1.

The apparatus 1 comprises a housing 2 secured in an opening formed in the base of a hopper 3 for particulate material such as a powdered chemical to be fed to an industrial boiler. The housing 2 is mounted in the opening by means of a flexible rubber ring 4 bolted at its inner peripheral edge to an annular flange 5 of the flange housing and bolted at its outer peripheral edge to the edge of the circular opening in the base of the hopper.

An inlet system for particulate material is provided at the top of the housing 2 and consists of an annular inlet opening 6 formed centrally of a convex upper surface 7 of the housing. The closure means 8 for the inlet opening 6 consists of a shield 9 vertically movable towards and away from the opening and having a generally flat under surface which together with the convex upper surface 7 of the housing defines an annular path leading to the inlet 6. The convex profile of the surface 7 means that the path narrows or constricts towards the inlet 5 te produce a localised low pressure zone so that particles drawn along the path tend to accelerate as they approach the inlet.

The shield 9 has an upper portion 10 formed with a screw thread for attachment of a conical particle deflector 11. Between an upper surface 12 of the shield 9 and a lower surface 13 of the deflector a gas outlet path 14 is defined for discharging gas into the body of particulate material which in use surrounds the inlet system. A vertical gas feed passage 16 extending centrally through the shield 9 is arranged to supply gas to the outlet path 14 via a piurality of radial passages 40.

The upper conical surface of the deflector 11 ensures that particles move under gravity towards the downstream end of the gas outlet path 14.

A pressure regulating valve 15 is provided centrally of the shield 9 to control the flow of gas from the gas feed passage 16 to the gas outlet path 14. The pressure regulating valve 15 consists of a valve member having a tapered lower end biased by a spring 17 into engagement with the upper opening of the passage 16. The valve 15 forms a loose fit in a cylindrical bore to provide a gap which communicates the gas outlet path 14 downstream of the valve member with the upper end of the valve member so that excess pressure in the gas outlet 14 acts in conjunction with the spring 17 to close the valve. Thus if a back pressure develops in the gas outlet path 14, for example due to the weight of particulate material when the hopper is full, the valve 15 tends to close and thereby prevents excess particles from entering the particle inlet 6.The hack pressure at which this occurs can be adjusted by rotation of a pressure adjusting screw mounted in the deflector 11 and engaging the upper end of the spring 17 to vary the amount of compression thereof.

The gas feed passage 16 is defined in its lower region hy a hollow push rod 18 which extends from a lower region of the housing 2 to a connection with the shield 9 so as to control the vertical opening and closing movement thereof. At its lower end the push rod 18 is connected to a flexible rubber diaphragm 19 which is downwardly biased by a compression spring 20, such bias being transmitted to the shield 9 to close the inlet 6. The push rod 18 is received in a central column 41 extending upwardly from a column support 42 and the compression spring 20 is located in an intermediate chamber 43 defined benath the column support 42 and above the diaphragm 19. The intermediate chamber 43 is vented to atmosphere via a small side opening (not shown) to ensure that low pressure is not developed in the chamber when the diaphraqm 19 moves downwardly, as discussed later.

The housing 2 is provided with a transport gas inlet 21 from which gas passes to a lower chamber 22 which communicates with the hollow push rod 18 defining the gas feed passage 16 for supplying the gas outlet path 14. Pressure developed in the chamber 22 causes the flexible diaphragm 19 to flex upwardly against the force of the spring 20 so as to move the push rod 18 upwardly and thereby open the inlet 6.

In the lower chamber 22 an eccentric flywheel 23 is rotatahly mounted by a bush 24. The flywheel is formed at its outer circumference with teeth 25 (see Fig. 2) arranged to face a nozzle 26 of the inlet 21 so that transport gas flowing through the nozzle causes rotation of the flywheel. The nozzle may typically have a diameter of 3/32 inches (2.4 mm). The mass of the flywheel is eccentrically distributed by varying its thickness in the circumferential direction, as seen in Fig. 1, and rotation of the eccentric flywheel causes the whole apparatus to vibrate in its flexible mounting ring 4.

A pipe 27 extends from the lower chamber 22 to a nozzle 28 arranged to discharge into a venturi 29 to

cause a reduced pressure in an upper chamber or cavity 30 downstream of the particle inlet 6. As a result particles are sucked through the inlet 6 to pass into an exit pipe 31 downstream of the venturi. The nozzle 28 may typically have a diameter of 0.14 inches (3.6 mm). The cavity 30 is formed with an opening 32 which draws outside air into the cavity during operation further to dilute the particles entrained in the flow of transport gas. The opening 32 may also, in the unintended event of over flow of particulate material from the hopper, prevent choking of the cavity 30 by spilling surplus material. If desired a further venturi or suction device may be disposed downstream of the exit pipe 31 to assist transport of powder to the eventual destination.

In operation, transport gas is supplied to the inlet 21 under pressure and before eventually exhausting through the exit pipe 31 with entrained particles the gas performs several functions, as follows. The gas rotates the flywheel 23 in the chamber 22, elevates the pressure in the chamber 22 so as to cause upward movement of the shield 9 to open the particle inlet 6, passes upwardly through the hollow push rod 18 to be discharged into the powder where it passes round the outer peripheral edge of the shield 9 before being drawn into the inlet 6 together with entrained powder, and passes along the pipe 27 to be discharged into the venturi 29 for lowering the pressure in cavity 30.

It will therefore be seen that the powder is first diluted with transport gas in the region of the gas outlet 14, is further diluted by air drawn in through opening 31, and is diluted again by gas discharged from the nozzle 28 into the venturi 29. It will also be noted that the gas used to drive the vibrator also performs the other functions and is not vented to atmosphere.

When the supply of transport gas is switched off the shield 9 moves downwardly to close the particle inlet 6 under the bias of the compression spring 20 acting on the push rod 18. The diaphragm 19 is also moved downwardly and because the intermediate chamber 43 is vented to atmosphere any tendency for particulate material to be sucked from cavity 30 to chamber 43 via the clearance between the push rod 18 and the central column 41 is prevented.

The vent also ensures that as wear occurs between the central column 41 and the push rod 18 the lower pressure in cavity 30 will tend to pull up air from the intermediate chamber 43 and further prevent the ingress of particulate material which over a period of tme could otherwise cause high wear.

Apart from the flexible rubber ring 4 and the flexible rubber diaphragm 19, the other components of the apparatus will generally be made of a metal such as steel.

It is to be clearly understood that there are no particular features of the foregoing specification, or of any claims appended hereto, which are at present regarded as being essential to the performance of the present invention, and that any one or more of such features or combinations thereof may therefore be included in, added to, omitted from or deleted from any of such claims if and when amended during the prosecution of this application or in the filing or prosecution of any divisional application based thereon. Furthermore the manner in which any of such features of the specification or claims are described or defined may be amended, broadened or otherwise modified in any manner which falls within the knowledge of a person skilled in the relevant art, for example so as to encompass, either implicitly or explicitly, equivalents or generalisations thereof.

Claims

CLAIMS:

1. Apparatus for connection to a body of particulate material and operable to entrain such material in a flow of transport gas, comprising an inlet for particulate material adapted to be disposed in the body thereof, a shield arranged above the inlet, and a transport gas outlet arranged to discharge gas into the body of particulate material above the shield such that the gas flows past the shield and towards the inlet so as to assist flow of the material into the inlet.

2. Apparatus as claimed in claim 1, wherein the transport gas outlet is annular in form.

3. Apparatus as claimed in claim 2, wherein the transport gas outlet comprises an upwardly facing conical surface located beneath a downwardly facing conical surface to define a conical gas flow passage therebetween, and gas supply means disposed centrally of the conical gas flow passage, whereby in operation the gas flows in a generally radially outward and downward direction.

4. Apparatus as claimed in claim 3, wherein the profiles of the upwardly and downwardly facing conical surfaces are such that the conical gas flow passage narrows in the downstream direction.

5. Apparatus as claimed in any preceding claim, further comprising control means arranged selectively to interrupt the flow of gas to the gas outlet to limit the maximum gas pressure developed in the region of the gas outlet.

6. Apparatus as claimed in any preceding claim, wherein the particulate material inlet is annular in form, and wherein a path is defined leading to said inlet, the area of the path transverse to the flow direction narrowing towards said inlet.

7. Apparatus as claimed in any preceding claim, further comprising downstream of the particulate material inlet a cavity through which the flow of gas with entrained particles passes in use and which has an opening communicating with atmosphere such that outside air is drawn into the cavity.

8. Apparatus as claimed in claim 7, further comprising downstream of the cavity a nozzle arranged to discharge transport gas into a venturi.

9. Apparatus as claimed in any preceding claim, wherein the particulate material inlet is provided with closure means normally biased to a closed position so as to be closed when the apparatus is not in operation, and automatically movable to an open position in response to gas pressure supplied to the transport gas flow system.

10. Apparatus as claimed in claim 9, further comprising a chamber arranged to receive transport gas upstream of the transport gas outlet, the chamber being at least partly defined by a flexible diaphragm to which the closure means is connected, whereby a change in pressure in the chamber when the gas supply is switched on causes flexing of the diaphragm and consequent opening of the closure means.

11. Apparatus as claimed in claim 9 or 10, wherein the shield arranged above the particulate material inlet acts as the closure member and is vertically upwardly movable from the closed position to the open position.

12. Apparatus as claimed in claim 11, wherein a hollow push rod connects the flexible diaphragm to the shield to effect opening and closing movement thereof, and the push rod provides a gas passage which communicates the chamber adjacent the diaphragm with the gas outlet arranged above the shield, the passage in the push rod acting as the feed to the gas outlet.

13. Apparatus as claimed in any preceding claim, further comprising vibration means for loosening the particulate material and thereby assisting entrainment thereof.

14. Apparatus as claimed in claim 13, wherein the vibration means is arranged to be driven by the transport gas supplied to the apparatus.

15. Apparatus as claimed in claim 13 or 14, further comprising means for mounting the apparatus

flexibly to a container for the particulate material so that substantially the whole apparatus is vibrated by operation of the vibration means, the flexible mounting means being arranged to be exposed to the inside of the container such that in use particulate material is in contact with the mounting means and is vibrated thereby.

16. Apparatus for connection to a body of particulate material and operable to entrain such material in a flow of transport gas, comprising an inlet for particulate material adapted to be disposed in the body thereof, a transport gas flow system arranged to be supplied with gas to produce low pressure downstream of the particulate material inlet such that in use material is drawn through the inlet and entrained in the gas flow, and closure means for the inlet normally biased to a closed position and automatically movable to an open position in response to gas pressure supplied to the transport gas flow system.

17. Apparatus for connection to a container of particulate material and operable to entrain such material in a flow of transport gas, comprising an inlet for particulate material, means for vibrating the apparatus, and means for flexibly mounting the apparatus to the container with the inlet for particulate material disposed in the container, the flexible mounting means being arranged to be exposed to the inside of the container such that in use particulate material is in contact with the mounting means and is vibrated thereby.

18. Apparatus for connection to a body of particulate material, substantially as hereinbefore described with reference to the accmpanying drawings.